The British Association at Edinburgh.

THE prospects of a first-rate meeting in Edinburgh are now assured. The journal, which extends to more than forty pages, shows that all the sections will have a full programme—in fact, the difficulty in several cases has been to fit the communications into the time available. The number of members already enrolled indicates that the total entry will exceed 2000, so that from a numerical, as well as from other points of view, the Edinburgh meeting is certain of success. The proof copy of the list of members shows that British science is to be strongly represented at the meeting. In the list are the names of many well-known men of science, including about one hundred fellows of the Royal Society. Three past-presidents of the Association will attend the meeting—Sir James Dewar, Sir Oliver Lodge, and Sir Edward Sharpey Schafer —in addition to Prof. Herdman, who resigns the office of president to Sir Edward Thorpe.

A goodly number of overseas and foreign men of science have signified their intention of being present at the meeting. Physics, mathematics, and chemistry are represented by Prof. Svante Arrhenius (Stockholm), Prof. H. E. Fierz (Zürich), Prof. F. M. Jaeger and Prof. Kapteyn (Gröningen), Dr. Irving Langmuir (New York), Prof. J. C. McLennan (Toronto), Dr. Hans Petterssen (Gothenberg), Prof. Volterra (Rome), and Prof. R. W. Wood (Johns Hopkins University) Geology and zoology have also a goodly representation of men of science from overseas. In the former section are Prof. Collet (Geneva), Prof. R. A. Daly (Harvard), Baron de Geer (Stockholm), and Prof. Kolderup (Bergen), while in the section of zoology are Prof. J. F. van Bemmelen and Prof. J. W. van Wijhe (Gröningen), Prof. Hérouard (Paris), and Prof. Vernon Kellogg (Washington). Other foreign representatives are Dr. Krogh (Copenhagen), in the section of physiology, Dr. Langfeld (Harvard), in the section of psychology, and Dr. J. P. Lotsy (Holland), in the section of botany. Most of these are to take part in the proceedings of the sections, either by presenting some communication on their recent work, or by joining in the discussions which have been arranged.

There will be a daily weather report for Edinburgh. The Meteorological Office, Air Ministry, has arranged that during the week over which the meetings of the British Association extend—September 7–14—a demonstration will be given daily of the methods employed in preparing the British daily weather map and in forecasting the weather in different districts of the country during the ensuing twenty-four hours. For this purpose a temporary branch of the Meteorological Office, Edinburgh, is being opened in the natural philosophy department of the university, in which building the meetings of Section A (Mathematics and Physics) are being held. This temporary office is being supplied with wireless apparatus capable of receiving all the different European synoptic messages. In addition, arrangements are being made for the receipt of weather messages from various centres by telegraph and telephone, including messages from ships in the Atlantic, and some of the information which is ordinarily collected by the Air Ministry for the purposes of aviation.

Most of the meteorological data thus collected will be represented on a large blackboard map which has been erected in the entrance hall of the natural philosophy department, where it can be seen by those attending the meetings. Some information chiefly referring to local or Scottish weather conditions will also be shown. The area over which the map extends is from Spitsbergen, in the north, to Africa, in the south, and from Warsaw to the Azores, and it is expected that the representation on it of the morning's weather throughout this area will be complete by 10 a.m.

A local daily weather report, embodying the more important data on the map, will be issued by 11 a.m., and a limited number of copies will be ready for issue soon after that hour. The report will include a "general inference" from the ascertained pressure distribution, as well as a special forecast for the Edinburgh district.

The demonstration will show what information can be obtained by the use of a suitable wireless receiving instrument, and how that information may be utilised; and it will illustrate the methods by which Scotland generally, and Edinburgh in particular, could be served in the matter of prompt and accurate information with regard to the weather of the day and its probable changes in the ensuing twenty-four hours.

J. H. ASHWORTH.

Some Aspects and Problems of Post-war Science, Pure and Applied.*

BY SIR T. EDWARD THORPE, C.B., D.Sc., Sc.D., LL.D., F.R.S., HON. F.R.S.EDIN., *President*.

THE British Association for the Advancement of Science owes its origin, and, in great measure, its specific aims and functions, to the public spirit and zeal for the interests of science of Scotsmen. Its virtual founder was Sir David Brewster; its scope and character were defined by Principal Forbes. In constitution it differed from the migratory scientific associations existing on the Continent, which mainly served to promote the social intercourse of their members by annual gatherings, in that it was to be a permanent organisation, with a settled establishment and headquarters, which should have not merely its yearly reunions, but which, "by methods and by influence peculiarly its own, should continue to operate during the intervals of these public assemblies, and should aspire to give an impulse to every part of the scientific system; to mature scientific enterprise; and to direct the labours requisite for discovery."

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* Presidential address delivered at the Edinburgh meeting of the British Association on September 7.

Although, for reasons of policy, it was decided that its first meeting of September 27, 1831, should be held at York, as the most central city for the three kingdoms, and its second and third meetings at the ancient Universities of Oxford and Cambridge respectively, it was inevitable that the Association should seize the earliest opportunity to visit the Metropolis of Scotland, where, as an historical fact, it may be said to have had its origin.

The meeting in this city of September 8, 1834, was noteworthy for many reasons. It afforded the first direct proof that the Association was fulfilling its purpose. This was shown by the popular appreciation which attended its activities, by the range and character of its reports on the state and progress of science, by the interest and value of its sectional proceedings, and by the mode in which its funds were employed. In felicitous terms the president of the preceding year, the Rev. Prof. Sedgwick, congratulated the gathering "on the increased strength in which they had assembled, in a place endeared to the feelings of every lover of science by so many delightful and elevating recollections, especially by the recollection of the great men whom it had fostered, or to whom it had given birth." In a few brief sentences Prof. Sedgwick indicated the great power which this Association is able to apply towards the advancement of science by combination and united action, and he supported his argument by pointing to the results which it had already achieved during the three short years of its existence. Prof. Sedgwick's words are no less true to-day. His contention that one of the most important functions of this philosophical union is to further what he termed the "commerce of ideas" by joint discussions on subjects of kindred interest, has been endorsed by the recent action of the Council in bringing the various sections into still closer touch with each other with a view to the discussion of common problems of general interest. This slight reorganisation of the work of the sections, which is in entire accord with the spirit and aims of the Association, as defined by its progenitors and formulated in its constitution, will take effect during the present meeting. Strictly speaking, such joint sectional discussions are not unknown in our history, and their utility and influence have been freely recognised. But hitherto the occasions have been more or less informal. They are now, it is hoped, to be part of the regular official procedure of the meetings, to which it is anticipated they will afford additional interest and value.

Another noteworthy change in our procedure is the introduction of discussions on the addresses of the presidents of sections. Hitherto these addresses have been formally read and never discussed. To the extent that they have been brief chronicles of the progress of the special departments of science with which the section is concerned they have given but little opportunity for discussion. With the greatly increased facilities which now exist for every worker to keep himself informed of the development of the branch of knowledge in which he is more particularly interested, such *résumés* have in great measure lost their true purpose, and there has, consequently, been a growing tendency of late years for such presidential addresses to deal with contemporary topics of general interest and of fundamental importance, affording ample opportunity for a free exchange of opinion. The experiment will certainly conduce to the interest of the proceedings of the sections, and will contribute to the permanent value of their work. We see in these several changes the development of ideas connected with the working of the Association which may be said to have had their birth at its first meeting in Edinburgh, eighty-seven years ago.

Sixteen years later—that is, on July 21, 1850—Edinburgh again extended her hospitality to the British Association, which then honoured itself by electing the learned principal of the united colleges of St. Salvator and St. Leonard, St. Andrews, to the presidential chair—at once a tribute to Sir David Brewster's eminence as a natural philosopher, and a grateful recognition of his services to this body in suggesting and promoting its formation.

On the occasion of his inaugural address, after a brief account of recent progress in science, made with the lucidity of expression which characterised all the literary efforts of the learned biographer of Newton and versatile editor of the *Edinburgh Encyclopaedia,* the *Edinburgh Magazine,* and the *Edinburgh Journal of Science,* the president dwelt upon the beneficent influence of the Association in securing a more general attention to the objects of science, and in effecting a removal of disadvantages of a public kind that impeded its progress. It was due largely to the action of the Association, assisted by the writings and personal exertions of its members, that the Government was induced to extend a direct national encouragement to science and to aid in its organisation.

Brewster had a lofty ideal of the place of science in the intellectual life of a community, and of the just position of the man of science in the social scale. In well-weighed words, the outcome of matured experience and of an intimate knowledge of the working of European institutions created for the advancement of science and the diffusion of knowledge, he pleaded for the establishment of a national institution in Britain possessing a class of resident members who should devote themselves wholly to science—with a place and station in society the most respectable and independent—"free alike," as Playfair put it, "from the embarrassments of poverty or the temptations of wealth." Such men, "ordained by the State to the undivided functions of science," would, he contended, do more and better work than those who snatch an hour or two from their daily toil or nightly rest.

This ideal of "combining what is insulated, and uniting in one great institution the living talent which is in active but undirected and unbefriended exercise around us," was not attained during Brewster's time, nor, notwithstanding the reiteration of incontrovertible argument during the past seventy years, has it been reached in our own.

I have been led to dwell on Sir David Brewster's association with this question of the relations of the State towards research for several reasons. Although he was not the first to raise it—for Davy more than a century ago made it the theme of presidential addresses, and brought his social influence to bear in the attempt to enlist the practical sympathy of the Government—no one more consistently urged its national importance or supported his case with a more powerful advocacy than the principal of the University of Edinburgh. It is only seemly, therefore, that on this particular occasion, and in this city of his adoption, where he spent so much of his intellectual energy, I should specially allude to it. Moreover, we can never forget what this Association owes to his large and fruitful mind. Every man is a debtor to his profession, from which he gains countenance and profit. That Brewster was an ornament to his is acknowledged by every lover of learning. That he endeavoured to be a help to it was gratefully recognised during his lifetime. After his death it was said of him that the improved position of men of science in our time is chiefly due to his exertions and his example.

I am naturally led to connect the meeting of 1850 with a still more memorable gathering of this Association in this city. In August, 1871—just more than half a century ago—the British Association again assembled in Edinburgh under the presidency of Lord Kelvin—then Sir William Thomson. It was an historic occasion by reason of the address which inaugurated its proceedings. Lord Kelvin, with characteristic force and insistence, still further elaborated the theme which had been so signal a feature of Sir David Brewster's address twenty-one years previously: "Whether we look to the honour of England," he said, "as a nation which ought always to be the foremost in promoting physical science, or to those vast economical advantages which must accrue from such establishments, we cannot but feel that experimental research ought to be made with us an object of national concern, and not left, as hitherto, exclusively to the private enterprise of self-sacrificing amateurs, and the necessarily inconsecutive action of our present Governmental Departments and of casual committees."

Lord Kelvin, as might have been anticipated, pleaded more especially for the institution of physical observatories and laboratories for experimental research, to be conducted by qualified persons, whose duties should be not teaching, but experimenting. Such institutions as then existed, he pointed out, afforded only a very partial and inadequate solution of a national need. They were, for the most part, "absolutely destitute of means, material, or *personnel* for advancing science, except at the expense of volunteers, or of securing that volunteers should be found to continue such little work as could then be carried on."

There were, however, even then, signs that the bread cast upon the waters was slowly returning after many days. The establishment of the Cavendish Laboratory at Cambridge, by the munificence of its then chancellor, was a notable achievement. Whilst in its constitution as part of a university discipline it did not wholly realise the ideal of the two presidents, under its successive directors, Prof. Clerk Maxwell, the late Lord Rayleigh, and Sir J. J. Thomson, it has exerted a profound influence upon the development of experimental physics, and has inspired the foundation of many similar educational institutions in this country. Experimental physics has thus received an enormous impetus during the last fifty years, and although in matters of science there is but little folding of the hands to sleep, "the divine discontent" of its followers has little cause for disquietude as regards the position of physics in this country.

In the establishment of the National Physical Laboratory we have an approach to the ideal which my predecessors had so earnestly advocated. Other presidents, among whom I would specially name the late Sir Douglas Galton, have contributed to this consummation. The result is a remarkable testimony to the value of organised and continuous effort on the part of the British Association in forming public opinion and in influencing Departmental action. It would, however, be ungrateful not to recall the action of the late Lord Salisbury—himself a follower of science and in full sympathy with its objects—in taking the first practical steps towards the creation of this magnificent national institution. I may be allowed, perhaps, to refer to this matter, as I have personal knowledge of the circumstances, being one of the few survivors of the Committee which Lord Salisbury caused to be formed, under the chairmanship of the late Lord Rayleigh, to inquire and report upon the expediency of establishing an institution in Great Britain upon the model of certain State-aided institutions already existing on the Continent, for the determination of physical constants of importance in the arts, for investigations in physical problems bearing upon industry, for the standardisation and verification of physical instruments, and for the general purposes of metrology. I do not profess to give the exact terms of the reference to the Committee, but in substance these were recognised to be the general aims of the contemplated institute. The evidence we received from many men of science, from Departmental officers, and from representatives of engineering and other industrial establishments was absolutely unanimous as to the great public utility of the projected laboratory. It need scarcely be said that the opportunity called forth all the energy and power of advocacy of Lord Kelvin, and I well remember with what strength of conviction he impressed his views upon the Committee. That the National Physical Laboratory has, under the ability, organising power, and business capacity of its first director, Sir Richard Glazebrook, abundantly justified its creation is recognised on all hands. Its services during the four years of war alone are sufficient proof of its national value. It has grown to be a large and rapidly increasing establishment, occupying itself with an extraordinary range of subjects, with a numerous and well-qualified staff, engaged in determinative and research work on practically every branch of pure and applied physics. The range of its activities has been further increased by the establishment since the war of co-ordinating research boards for physics, chemistry, engineering, and radio-research. Government Departments have learned to appreciate its services. The photometry division, for example, has been busy on experiments on navigation lamps for the Board of Trade, on miners' lamps for the Home Office, and on motor-car head-lamps for the Ministry of Transport, and on the lighting of the National Gallery and the Houses of Parliament. Important work has been done on the forms of ships, on the steering and manœuvring of ships, on the effect of waves on ship resistance, on the interaction between passing ships, on seaplane floats, and on the hulls of flying-boats.

It is also actively engaged in the study of problems connected with aviation, and has a well-ordered department for aerodynamical research.

It can already point to a long and valuable series of published researches, which are acknowledged to be among the most important contributions to pure and applied physics which this country has made during recent years.

I may be pardoned, I hope, for another personal reference if I recall that it was at the Edinburgh meeting, under Lord Kelvin's presidency, fifty years ago, that I first became a member of this Association, and had the honour of serving it as one of the secretaries of its chemical section. Fifty years is a considerable span in the life of an individual, but it is a relatively short period in the history of science. Nevertheless, those fifty years are richer in scientific achievement and in the importance and magnitude of the utilitarian applications of practically every branch of science than any preceding similar interval. The most cursory comparison of the state of science, as revealed in his comprehensive address, with the present condition of those departments on which he chiefly dwelt, will suffice to show that the development has been such that even Lord Kelvin's penetrative genius, vivid imagination, and sanguine temperament could hardly have anticipated. No previous half-century in the history of science has witnessed such momentous and far-reaching achievements. In pure chemistry it has seen the discovery of argon by Rayleigh, of radium by Mme. Curie, of helium as a terrestrial element by Ramsay, of neon, xenon, and krypton by Ramsay and Travers, the production of helium from radium by Ramsay and Soddy, and the isolation of fluorine by Moissan. These are undoubtedly great discoveries, but their value is enormously enhanced by the theoretical and practical consequences which flow from them.

In applied chemistry it has witnessed the general application of the Gilchrist-Thomas process of iron-purification, the production of calcium cyanamide by the process of Frank and Caro, Sabatier's process of hydrogenation, a widespread application of liquefied gases, and Haber's work on ammonia synthesis—all manufacturing processes which have practically revolutionised the industries with which they are concerned.

In pure physics it has seen the rise of the electron theory, by Lorentz; Hertz's discovery of electro-magnetic waves; the investigation of cathode rays by Lenard, and the elucidation of crystal structure by Bragg.

It has seen, moreover, the invention of the telephone, the establishment of incandescent lighting, the electric transmission of force, the invention of the cinematograph, of wireless telegraphy, the application of the Röntgen rays, and the photographic reproduction of colour.

In physical chemistry it has witnessed the creation of stereochemistry by Van t'Hoff and Le Bel, Gibbs's work on the phase rule, Van t'Hoff's theory of solutions, Arrhenius's theory of ionic dissociation, and Nernst's theory of the galvanic cell.

Such a list is far from complete, and might be greatly extended; but it will at least serve to indicate the measure of progress which the world owes to the development and application during the last fifty years of the two sciences—physics and chemistry—to which Lord Kelvin specially referred.

The more rapid dissemination of information concerning the results of recent or contemporary investigation, which Lord Kelvin so strongly urged as "an object to which the powerful action of the British Association would be thoroughly appropriate," has been happily accomplished. The timely aid of the Association in contributing to the initial expense of preparing and publishing monthly abstracts of foreign chemical literature by the Chemical Society is gratefully remembered by British chemists. The example has been followed by the greater number of our scientific and technical societies, and the results of contemporary inquiry in every important branch of pure and applied science are now quickly brought to the knowledge of all interested workers. In fact, as regards the particular branch of science with which I am more directly concerned, the arrangements for the preparation and dissemination of abstracts of contemporary foreign chemical literature are proving to be a veritable embarrassment of riches, and there is much need for co-operation among the various distributing societies. This need is especially urgent at the present time owing to the greatly increased cost of paper, printing, binding, and indeed of every item connected with publication, which expense, of course, ultimately falls upon the various societies and their members. The problem, which has already received some attention from those entrusted with the management of the societies referred to, is not without its difficulties, but these are not insoluble. There is little doubt that a resolute and unanimous effort to find a solution would meet with success.

The present high cost of book production, which in the case of specialised books is about three times what it was in 1914, is exercising a most prejudicial effect upon the spread of scientific knowledge. Books on science are not generally among the "best sellers." They appeal to a comparatively limited and not particularly wealthy public, largely composed of the professional classes who have suffered in no small measure from the economic effects of the war The present high price of this class of literature is to the public detriment. Eventually it is no less to the detriment of the printing and publishing trades. Publishers are well aware of this fact, and attempts are being made by discussions between employers and the executives of the Typographical Association and other societies of compositors to reach an equitable solution, and it is greatly to be hoped that it will be speedily found.

All thinking men are agreed that science is at the basis of national progress. Science can develop only by research. Research is the mother of discovery, and discovery of invention. The industrial position of a nation, its manufactures and commerce, and ultimately its wealth, depend upon invention. Its welfare and stability largely rest upon the equitable distribution of its wealth. All this seems so obvious, and has been so frequently and so convincingly stated, that it is superfluous to dwell upon it in a scientific gathering to-day.

A late distinguished Admiral, you may remember, insisted on the value of reiteration. On this particular question it was never more needed than now. The crisis through which we have recently passed requires it in the interests of national welfare. Of all post-war problems to engage our serious attention, none is more important in regard to our position and continued existence than the nation's attitude towards science and scientific research, and there is no more opportune time than the present in which to seek to enforce the teaching of one of the most pregnant lessons of our late experience.

It is, unfortunately, only too true that the industrial world has in the past underrated the value of research. One indication that the nation is at length aroused to its importance is to be seen in the establishment of the Department of Scientific and Industrial Research, with its many subordinate associations. The outbreak of the Great War, and much in its subsequent history, revealed, as we all know, many national shortcomings, due to our indifference to, and actual neglect of, many things which are at the root of our prosperity and security. During the war, and at its close, various attempts, more or less unconnected, were made to find a remedy. Of the several committees and boards which were set up, those which still exist have now been co-ordinated and brought under the control of a central organisation—the Department of Scientific and Industrial Research. Research has now become a national and State-aided object. For the first time in our history its pursuit with us has been organised by Government action. As thus organised it seeks to fulfil the aspirations to which I have referred, whilst meeting many of the objections which have been urged against the endowment of research. It must be recognised that modern ideas of democracy are adverse to the creation of places to which definite work is not assigned and from which definite results do not emanate. This objection, which strikes at the root of the establishment of such an institution as Sir David Brewster contemplated, is, to a large extent, obviated by the scheme of the Department of Scientific and Industrial Research. It does not prescribe or fetter research, but, whilst aiding by personal payments the individual worker, leaves him free to pursue his inquiry as he thinks best. Grants are made, on the recommendation of an Advisory Council of experts, to research workers in educational institutions and elsewhere, in order to promote research of high character on fundamental problems of pure science or in suitable cases on problems of applied science. Of the boards and committees and similar organisations established prior to or during the war, or subsequent to it, with one or two exceptions, all are now directly under the Department. They deal with a wide range of subjects, such as the Building Research Board, established early in 1920 to organise and supervise investigations on building materials and construction, to study structural failures, and to fix standards for structural materials. The Food Investigation Board deals with the preservation by cold of food, and with the engineering problems of cold storage, with the chemistry of putrefaction, and the agents which induce it, with the bionomics of moulds, and the chemistry of edible oils and fats. The Fuel Research Board is concerned with the immediate importance of fuel economy and with investigations of the questions of oil-fuel for the Navy and Mercantile Marine, the survey of the national coal resources, domestic heating, air pollution, pulverised fuel, utilisation of peat, the search for possible substitutes for natural fuel oil, and for practicable sources of power alcohol.

The Geological Survey Board has taken over the Geological Survey of Great Britain and the control of the Museum of Practical Geology. The maintenance of the National Physical Laboratory, originally controlled by a general board and an executive committee appointed by the president and council of the Royal Society, is now transferred to the Department of Scientific and Industrial Research. A Mines Research Committee and a Mine Rescue Apparatus Committee are attached to the Department. The former is concerned with such questions as the determination of the geothermic gradient, the influence of temperature of intake and return air on strata, the effect of seasonal changes on strata temperature of intakes, the cooling effect due to the evolution of fire-damp, heat production from the oxidation of timber, etc. The Department is also directing inquiries on the preservation and restoration of antique objects deposited in the British Museum. It is concerned with the gauging of rivers and tidal currents, with special reference to a hydrographical survey of Great Britain in relation to the national resources of water-power. In accordance with the Government policy, four co-ordinating boards have been established to organise scientific work in connection with the fighting forces, so as to avoid unnecessary overlapping and to provide a single direction and financial control. The four boards deal, respectively, with chemical and physical problems, problems of radio-research, and engineering. These boards have attached to them various committees dealing with special inquiries, some of which will be carried out at the National Physical Laboratory. The Government have also authorised the establishment of a Forest Products Research Board.

The Department is further empowered to assist learned or scientific societies and institutions in carrying out investigations. Some of these were initiated prior to the war, and were likely to be abandoned owing to lack of funds. Whenever the investigation has a direct bearing upon a particular industry that had not hitherto been able to establish a research association, it has been a condition of a grant that the institution directing the research should obtain contributions towards the cost on a *l.* for *l.* basis, either directly through its corporate funds, or by special subscriptions from interested firms. On the formation of the appropriate association the research is, under suitable safeguards, transferred to it for continuance. The formation of a number of research associations has thus been stimulated, dealing, for example, with scientific instruments, non-ferrous metals, glass, silk, refractories, electrical and allied industries, pottery, etc.

Grants are made to research associations formed voluntarily by manufacturers for the purposes of research, from a fund of a million sterling, placed at the disposal of the Research Department for this purpose. Such associations, to be eligible for the grant, must submit articles of association for the approval of the Department and the Board of Trade. If these are approved, licences are issued by the Board of Trade recognising the associations as limited liability companies working without profits. Subscriptions paid to an association by contributing firms are recognised by the Board of Inland Revenue as business costs of the firms, and are not subject to income or excess profits taxes. The income of the association is similarly free of income tax. Grants are ordinarily made to these associations on the basis of 1*l.* for every 1*l.* raised by the association between limits depending upon the particular industry concerned. In the case of two research associations grants are made at a higher rate than *l.* for *l.*, as these industries are regarded as having a special claim to State assistance on account of their "pivotal" character. The results of research are the sole property of the association making them, subject to certain rights of veto possessed by the Department for the purposes of ensuring that they are not communicated to foreign countries, except with the consent of the Department, and that they may be made available to other interested industries and to the Government itself on suitable terms.

These arrangements have been found to be generally satisfactory, and at the present time twenty-four of such research associations have been formed to whom licences have been issued by the Board of Trade. Others are in process of formation, and may be expected to be at work at an early date. These research associations are concerned with nearly all our leading industries. The official addresses of most of them are in London; others have their headquarters in Manchester, Leeds, Sheffield, Birmingham, Northampton, Coventry, Glasgow, and Belfast.

The Department has further established a Records Bureau, which is responsible for receiving, abstracting, filing and collating communications from research workers, boards, institutions, or associations related to, or supervised by, the Department. This information is regarded as confidential, and will not be communicated except in writing, and after consultation with the research worker or organisation from which it has been received. Also such non-confidential information as comes into the possession of the Department which is of evident or probable value to those working in touch with the Department is collected and filed in the bureau and made generally available.

It is also a function of the bureau to effect economy in preventing repetition and overlapping of investigations and in ensuring that the fullest possible use is made of the results of research. Thus the programmes of research associations are compared in order to ensure that researches are not unwittingly duplicated by different research associations. Sometimes two or more research associations may be interested in one problem from different points of view, and when this occurs it may be possible for the bureau to arrange a concerted attack upon the common problem, each research association undertaking that phase of the work in which it is specially interested and sharing in the general results.

As researches carried out under the Department frequently produce results for which it is possible to take out patents, careful consideration has been given to the problems of policy arising on this subject, and other Government Departments also interested have been freely consulted. As the result, an Inter-Departmental Committee has been established with the following terms of reference:—

(1) To consider the methods of dealing with inventions made by workers aided or maintained from public funds, whether such workers be engaged (*a*) as research workers, or (*b*) in some other technical capacity, so as to give a fair reward to the inventor and thus encourage further effort, to secure the utilisation in industry of suitable inventions and to protect the national interest; and

(2) To outline a course of procedure in respect of inventions arising out of State-aided or supported work which shall further these aims and be suitable for adoption by all Government Departments concerned.

About forty patents have been taken out by the Department jointly with the inventors and other interested bodies, but of these nine have afterwards been abandoned. At least five patents have been developed to such a stage as to be ready for immediate industrial application.

It will be obvious from this short summary of the activities of the Department of Scientific and Industrial Research, based upon information kindly supplied to me by Sir Francis Ogilvie, that this great scheme of State-aided research has been conceived and is administered on broad and liberal lines. A considerable number of valuable reports from its various boards and committees have already been published, and others are in the press, but it is, of course, much too soon to appreciate the full effects of their operations; but it can scarcely be doubted that they are bound to exercise a profound influence upon industries which ultimately depend upon discovery and invention. The establishment of the Department marks an epoch in our history. No such comprehensive organisation for the application of science to national needs has ever been created by any other State. We may say we owe it directly to the Great War. Even from the evil of that great catastrophe there is some soul of goodness would we observingly distil it out.

I turn now to a question of scientific interest which is attracting general attention at the present time. It is directly connected with Lord Kelvin's address fifty years ago.

The molecular theory of matter—a theory which in its crudest form has descended to us from the earliest times, and which has been elaborated by various speculative thinkers through the intervening ages, scarcely rested upon an experimental basis until within the memory of men still living. When Lord Kelvin spoke in 1871, the best-established development of the molecular hypothesis was exhibited in the kinetic theory of gases as worked out by Joule, Clausius, and Clerk Maxwell. As he then said, no such comprehensive molecular theory had ever been even imagined before the nineteenth century; but, with the eye of faith, he clearly perceived that, definite and complete in its area as it was, it was "but a well-drawn part of a great chart, in which all physical science will be represented with every property of matter shown in dynamical relation to the whole. The prospect we now have of an early completion of this chart is based on the assumption of atoms; but there can be no permanent satisfaction to the mind in explaining heat, light, elasticity, diffusion, electricity and magnetism, in gases, liquids, and solids, and describing precisely the relations of these different states of matter to one another by statistics of great numbers of atoms when the properties of the atom itself are simply assumed. When the theory, of which we have the first instalment in Clausius's and Maxwell's work, is complete, we are but brought face to face with a superlatively grand question: What is the inner mechanism of the atom?"

If the properties and affections of matter are dependent upon the inner mechanism of the atom, an atomic theory, to be valid, must comprehend and explain them all. There cannot be one kind of atom for the physicist and another for the chemist. The nature of chemical affinity and of valency, the modes of their action, the difference in characteristics of the chemical elements, even their number, internal constitution, periodic position, and possible isotopic rearrangements must be accounted for and explained by it. Fifty years ago chemists, for the most part, rested in the comfortable belief of the existence of atoms in the restricted sense in which Dalton, as a legacy from Newton, had imagined them. Lord Kelvin, unlike the chemists, had never been in the habit of "evading questions as to the hardness or indivisibility of atoms by virtually assuming them to be infinitely small and infinitely numerous." Nor, on the other hand, did he realise, with Boscovich, the atom "as a mystic point endowed with inertia and the attribute of attracting or repelling other such centres." Science advances not so much by fundamental alterations in its beliefs as by additions to them. Dalton would equally have regarded the atom "as a piece of matter of measurable dimensions, with shape, motion, and laws of action, intelligible subjects of scientific investigation."

In spite of the fact that the atomic theory, as formulated by Dalton, has been generally accepted for nearly a century, it is only within the last few years that physicists have arrived at a conception of the structure of the atom sufficiently precise to be of service to chemists in connection with the relation between the properties of elements of different kinds, and in throwing light on the mechanism of chemical combination.

This further investigation of the "superlatively grand question—the inner mechanism of the atom"—has profoundly modified the basic conceptions of chemistry. It has led to a great extension of our views concerning the real nature of the chemical elements. The discovery of the electron, the production of helium in the radioactive disintegration of atoms, the recognition of the existence of isotopes, the possibility that all elementary atoms are composed either of helium atoms or of atoms of hydrogen and helium, and that these atoms, in their turn, are built up of two constituents, one of which is the electron, a particle of negative electricity the mass of which is only 1/1800 of that of an atom of hydrogen, and the other a particle of positive electricity the mass of which is practically identical with that of the same atom—the outcome, in short, of the collective work of Soddy, Rutherford, J. J. Thomson, Collie, Moseley, and others—are pregnant facts which have completely altered the fundamental aspects of the science. Chemical philosophy has, in fact, now definitely entered on a new phase.

Looking back over the past, some indications of the coming change might have been perceived wholly unconnected, of course, with the recent experimental work which has served to ratify it. In a short paper entitled, "Speculative Ideas respecting the Constitution of Matter," originally published in 1863, Graham conceived that the various kinds of matter, now recognised as different elementary substances, may possess one and the same ultimate or atomic molecule existing in different conditions of movement. This idea, in its essence, may be said to be as old as the time of Leucippus. To Graham as to Leucippus, "the action of the atom as one substance taking various forms by combinations unlimited, was enough to account for all the phenomena of the world. By separation and union with constant motion all things could be done." But Graham developed the conception by independent thought, and in the light of experimentally ascertained knowledge which the world owes to his labours. He might have been cognisant of the speculations of the Greeks, but there is no evidence that he was knowingly influenced by them. In his paper, Graham uses the terms "atom" and "molecule," if not exactly in the same sense that modern teaching demands, yet in a sense very different from that hitherto required by the limitations of contemporary chemical doctrine. He conceives of a lower order of atoms than the chemical atom of Dalton, and founds on his conception an explanation of chemical combination based upon a fixed combining measure, which he terms the *metron,* its relative weight being one for hydrogen, sixteen for oxygen, and so on with the other so-called "elements." Graham, in fact, like Davy before him, never committed himself to a belief in the indivisibility of the Daltonian atom. The original atom may, he thought, be far down.

The idea of a primordial yle, or of the essential unity of matter, has persisted throughout the ages, and, in spite of much experimental work, some of it of the highest order, which was thought to have demolished it, it has survived, revivified and supported by analogies and arguments drawn from every field of natural inquiry. This idea, of course, was at the basis of the hypothesis of Prout, which, even as modified by Dumas, was held to be refuted by the monumental work of Stas. But, as pointed out by Marignac and Dumas, anyone who will impartially look at the facts can scarcely escape the feeling that there must be some reason for the frequent recurrence of atomic weights differing by so little from the numbers required by the law which the work of Stas was supposed to disprove. The more exact study within recent years of the methods of determining atomic weights and the great improvement in experimental appliances and technique, combined with a more rigorous standard of accuracy demanded by a general recognition of the far-reaching importance of an exact knowledge of these physical constants, have resulted in intensifying the belief that some natural law must be at the basis of the fact that so many of the most carefully determined atomic weights on the oxygen standard are whole numbers. Nevertheless, there were well-authenticated exceptions which seemed to invalidate its universality. The proved fact that a so-called element may be a mixture of isotopes—substances of the same chemical attributes, but of varying atomic weight—has thrown new light on the question. It is now recognised that the fractional values independently established in the case of any one element by the most accurate experimental work of various investigators are, in effect, "statistical quantities" dependent upon a mixture of isotopes. This result, indeed, is a necessary corollary of modern conceptions of the inner mechanism of the atom. The theory that all elementary atoms are composed of helium atoms, or of helium and hydrogen atoms, may be regarded as an extension of Prout's hypothesis, with, however, this important distinction, that whereas Prout's hypothesis was at best a surmise, with little, and that little only weak, experimental evidence to support it, the new theory is directly deduced from well-established facts. The hydrogen isotope, H_3, first detected by Sir J. J. Thomson, of which the existence has been confirmed by Aston, would seem to be an integral part of atomic structure. Rutherford, by the disruption of oxygen and nitrogen, has also isolated a substance of mass 3 which enters into the structure of atomic nuclei, but which he regards as an isotope of helium, which itself is built up of four hydrogen nuclei, together with two cementing electrons. The atomic nuclei of elements of even atomic number would appear to be composed of helium nuclei only, or of helium nuclei with cementing electrons; whereas those of elements of odd atomic number are made up of helium and hydrogen nuclei together with cementing electrons. In the case of the lighter elements of the latter class, the number of hydrogen nuclei associated with the helium nuclei is invariably three, except in that of nitrogen, where it is two. The frequent occurrence of this group of three hydrogen nuclei indicates that it is structurally an isotope of hydrogen with an atomic weight of three and a nuclear charge of one. It is surmised that it is identical with the hypothetical "nebulium" from which our "elements" are held by astro-physicists to be originally produced in the stars through hydrogen and helium.

These results are of extraordinary interest as bearing on the question of the essential unity of matter and the mode of genesis of the elements. Members of the British Association may recall the suggestive address on this subject of the late Sir William Crookes, delivered to the Chemical Section at the Birmingham meeting of 1886, in which he questioned whether there is absolute uniformity in the mass of the atoms of a chemical element, as postulated by Dalton. He thought, with Marignac and Schutzenberger, who had previously raised the same doubt, that it was not improbable that what we term an atomic weight merely represents a mean value around which the actual weights of the atoms vary within narrow limits, or, in other words, that the mean mass is "a statistical constant of great stability." No valid experimental evidence in support of this surmise was or could be offered at the time it was uttered. Maxwell pointed out that the phenomena of gaseous diffusion, as then ascertained, would seem to negative the supposition. If hydrogen, for example, were composed of atoms of varying mass, it should be possible to separate the lighter from the heavier atoms by diffusion through a porous septum. "As no chemist," said Maxwell, "has yet obtained specimens of hydrogen differing in this way from other specimens, we conclude that all the molecules of hydrogen are of sensibly the same mass, and not merely that their mean mass is a statistical constant of great stability."[1] But against this it may be doubted whether any chemist had ever made experiments sufficiently precise to solve this point.

The work of Sir Norman Lockyer on the spectroscopic evidence for the dissociation of "elementary" matter at transcendental temperatures, and the possible synthetic intro-stellar production of elements, through the helium of which he originally detected the existence, will also find its due place in the history of this new philosophy.

Sir J. J. Thomson was the first to afford direct evidence that the atoms of an element, if not exactly of the same mass, were at least approximately so, by his method of analysis of positive rays. By an extension of this method Dr. F. W. Aston has succeeded in showing that a number of elements are in reality mixtures of isotopes. It has been proved, for example, that neon, which has a mean atomic weight of about 20.2, consists of two isotopes having the atomic weights respectively of 20 and 22, mixed in the proportion of 90 per cent. of the former with 10 per cent. of the latter. By fractional diffusion through a porous septum an apparent difference of density of 0·7 per cent. between the lightest and heaviest fractions was obtained. The kind of experiment which Maxwell imagined proved the invariability of the hydrogen atom has sufficed to show the converse in the case of neon.

The element chlorine has had its atomic weight repeatedly determined, and, for special reasons, with the highest attainable accuracy. On the oxygen standard it is 35·46, and this value is accurate to the second decimal place. All attempts to prove that it is a whole number—35 or 36—have failed. When, however, the gas is analysed by the same method as that used in the case of neon it is found to consist of at least two isotopes of relative mass 35 and 37. There is no evidence whatever of an individual substance having the atomic weight 35·46. Hence chlorine is to be regarded as a complex element consisting of two principal isotopes of atomic weights 35 and 37 present in such proportion as to afford the mean mass 35·46. The atomic weight of chlorine has been so frequently determined by various observers and by various methods with practically identical results that it seems difficult to believe that it consists of isotopes present in definite and invariable proportion. Dr. Aston meets this objection by pointing out that all the accurate determinations have been made with chlorine derived originally from the same source, the sea, which has been perfectly mixed for æons. If samples of the element could be obtained from some other original source, it is possible that other values of atomic weight would be obtained, exactly as in the case of lead, in which the existence of isotopes in the metal found in various radioactive minerals was first conclusively established.

Argon, which has an atomic weight of 39·88, was found to consist mainly of an isotope having an atomic weight of 40, associated to the extent of about 3 per cent. with an isotope of atomic weight 36. Krypton and xenon are far more complex. The former would appear to consist of six isotopes, 78, 80, 82, 83, 84, 86; the latter of five isotopes, 129, 131, 132, 134, 136.

Fluorine is a simple element of atomic weight 19. Bromine consists of equal quantities of two isotopes, 79 and 81. Iodine, on the contrary, would appear to be a simple element of atomic weight 127. The case of tellurium is of special interest in view of its periodic relation to iodine, but the results of its examination up to the present are indefinite.

Boron and silicon are complex elements, each consisting of two isotopes, 10 and 11, and 28 and 29, respectively.

Sulphur, phosphorus, and arsenic are apparently simple elements. Their accepted atomic weights are practically integers.

All this work is so recent that there has been little opportunity, as yet, of extending it to any considerable number of the metallic elements. These, as will be obvious from the nature of the methods employed, present special difficulties. It is, however, highly probable that mercury is a mixed element consisting of many isotopes. These have been partially separated by Brönsted and Hevesy by fractional distillation at very low pressures, and have been shown to vary very slightly in density. Lithium is found to consist of two isotopes, 6 and 7. Sodium is simple, potassium and rubidium are complex, each of the two latter elements consisting, apparently, of two isotopes. The accepted atomic weight of cæsium, 132·81, would indicate complexity, but the mass spectrum shows only one line at 133. Should this be confirmed, cæsium would afford an excellent test case. The accepted value for the atomic weight is sufficiently far removed from a whole number to render further investigation desirable.

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[1] Clerk Maxwell, art. "Atom," *Ency. Brit.*, 9th ed.

This imperfect summary of Dr. Aston's work is mainly based upon the account he recently gave to the Chemical Society. At the close of his lecture he pointed out the significance of the results in relation to the periodic law. It is clear that the order of the chemical or "mean" atomic weights in the periodic table has no practical significance; anomalous cases, such as argon and potassium, are simply due to the relative proportions of their heavier and lighter isotopes. This does not necessarily invalidate or even weaken the periodic law, which still remains the expression of a great natural truth. That the expression as Mendeléeff left it is imperfect has long been recognised. The new light we have now gained has gone far to clear up much that was anomalous, especially Moseley's discovery that the real sequence is the atomic number, not the atomic weight. This is one more illustration of the fact that science advances by additions to its beliefs rather than by fundamental or revolutionary changes in them.

The bearing of the electronic theory of matter, too, on Prout's discarded hypothesis that the atoms of all elements were themselves built up of a primordial atom—his *protyle,* which he regarded as probably identical with hydrogen—is too obvious to need pointing out. In a sense, Prout's hypothesis may be said to be now re-established, but with this essential modification—the primordial atoms he imagined are complex and are of two kinds—atoms of positive and negative electricity—respectively known as protons and electrons. These, in Dr. Aston's words, are the standard bricks that Nature employs in her operations of element building.

The true value of any theory consists in its comprehensiveness and sufficiency. As applied to chemistry, this theory of "the inner mechanism of the atom" must explain all its phenomena. We owe to Sir J. J. Thomson its extension to the explanation of the periodic law, the atomic number of an element, and of that varying power of chemical combination in an element we term valency. This explanation I give substantially in his own words. The number of electrons in an atom of the different elements has now been determined, and has been found to be equal to the atomic number of the element, that is to the position which the element occupies in the series when the elements are arranged in the order of their atomic weights. We know now the nature and quantity of the materials of which the atoms are made up. The properties of the atom will depend not only upon these factors, but also upon the way in which the electrons are arranged in the atom. This arrangement will depend on the forces between the electrons themselves and also on those between the electrons and the positive charges or protons. One arrangement which naturally suggested itself is that the positive charges should be at the centre with the negative electrons around it on the surface of a sphere. Mathematical investigation shows that this is a possible arrangement if the electrons on the sphere are not too crowded. The mutual repulsion of the electrons resents overcrowding, and Sir J. J. Thomson has shown that when there are more than a certain number of electrons on the sphere, the attraction of a positive charge, limited as in the case of the atom in magnitude to the sum of the charges on the electrons, is not able to keep the electrons in stable equilibrium on the sphere, the layer of electrons explodes, and a new arrangement is formed. The number of electrons which can be accommodated on the outer layer will depend upon the law of force between the positive charge and the electrons. Sir J. J. Thomson has shown that this number will be eight with a law of force of a simple type.

To show the bearing of this result as affording an explanation of the periodic law, let us, to begin with, take the case of the atom of lithium, which is supposed to have one electron in the outer layer. As each element has one more free electron in its atom than its predecessor, glucinum, the element next in succession to lithium, will have two electrons in the outer layer of its atom, boron will have three, carbon four, nitrogen five, oxygen six, fluorine seven, and neon eight. As there cannot be more than eight electrons in the outer layer, the additional electron in the atom of the next element, sodium, cannot find room in the same layer as the other electrons, but will go outside, and thus the atom of sodium, like that of lithium, will have one electron in its outer layer. The additional electron, in the atom of the next element, magnesium, will join this, and the atom of magnesium, like that of glucinum, will have two electrons in the outer layer. Again, aluminium, like boron, will have three; silicon, like carbon, four; phosphorus, like nitrogen, five; sulphur, like oxygen, six; chlorine, like fluorine, seven; and argon, like neon, eight. The sequence will then begin again. Thus the number of electrons, one, two, three, up to eight, in the outer layer of the atom, will recur periodically as we proceed from one element to another in the order of their atomic weights, so that any property of an element which depends on the number of electrons in the outer layer of its atom will also recur periodically, which is precisely that remarkable property of the elements which is expressed by the periodic law of Mendeléeff, or the law of octaves of Newlands.

The valency of the elements, like their periodicity, is a consequence of the principle that equilibrium becomes unstable when there are more than eight electrons in the outer layer of the atom. For on this view the chemical combination between two atoms, A and B, consists in the electrons of A getting linked up with those of B. Consider an atom like that of neon, which has already eight electrons in its outer layer; it cannot find room for any more, so that no atoms can be linked to it, and thus it cannot form any compounds. Now take an atom of fluorine, which has seven electrons in its outer layer; it can find room for one, but only one, electron, so that it can unite with one, but not with more than one, atom of an element like hydrogen, which has one electron in the outer layer. Fluorine, accordingly, is monovalent. The oxygen atom has six electrons; it has, therefore, room for two more, and so can link up with two atoms of hydrogen: hence oxygen is divalent. Similarly nitrogen, which has five electrons and three vacant places, will be trivalent, and so on. On this view an element should have two valencies, the sum of the two being equal to eight. Thus, to take oxygen as an example, it has only two vacant places, and so can find room only for the electrons of two atoms; it has, however, six electrons available for filling up the vacant places in other atoms, and as there is only one vacancy to be filled in a fluorine atom the electrons in an oxygen atom could fill up the vacancies in six fluorine atoms, and thereby attach these atoms to it. A fluoride of oxygen of this composition remains to be discovered, but its analogue, SF_6, first made known by Moissan, is a compound of this type. The existence of two valencies for an element is in accordance with views put forward some time ago by Abegg and Bödlander. Prof. Lewis and Dr. Irving Langmuir have developed, with great ingenuity and success, the consequences which follow from the hypothesis that an octet of electrons surrounds the atoms in chemical compounds.

The term "atomic weight" has thus acquired for the chemist an altogether new and much wider significance. It has long been recognised that it has a far deeper import than as a constant useful in chemical arithmetic. For the ordinary purposes of quantitative analysis, of technology, and of trade, these constants may be said to be now known with sufficient accuracy; but, in view of their bearing on the great problem of the essential nature of matter and on the "superlatively grand question, What is the inner mechanism of the atom?" they become of supreme importance. Their determination and study must now be approached from entirely new points of view and by the conjoint action of chemists and physicists. The existence of isotopes has enormously widened the horizon. At first sight it would appear that we should require to know as many atomic weights as there are isotopes, and the chemist may well be appalled at such a prospect. All sorts of difficulties start up to affright him, such as the present impossibility of isolating isotopes in a state of individuality, their possible instability, and the inability of his quantitative methods to establish accurately the relatively small differences to be anticipated. All this would seem to make for complexity. On the other hand, it may eventually tend towards simplification. If, with the aid of the physicist, we can unravel the nature and configuration of the atom of any particular element, and determine the number and relative arrangement of the constituent protons and electrons, it may be possible to arrive at the atomic weight by simple calculation, on the assumption that the integer rule is mathematically valid. This, however, is almost certainly not the case, owing to the influence of "packing." The little differences, in fact, may make all the difference. The case is analogous to that of the so-called gaseous laws in which the departures from their mathematical expression have been the means of elucidating the physical constitution of the gases and of throwing light upon such variations in their behaviour as have been observed to occur. There would appear, therefore, ample scope for the chemist in determining with the highest attainable accuracy the departures from the whole-number rule, since it is evident that much depends upon their exact extent.

These considerations have already engaged the attention of chemists. For some years past a small International Committee, originally appointed in 1903, has made and published an annual report in which they have noted such determinations of atomic weight as have been made during the year preceding each report, and they have from time to time made suggestions for the amendment of the tables of atomic weights, published in text-books and chemical journals, and in use in chemical laboratories. In view of recent developments, the time has now arrived when the work of this International Committee must be reorganised and its aims and functions extended. The mode in which this should be done has been discussed at the meeting in Brussels, in June last, of the International Union of Chemistry Pure and Applied, and has resulted in strengthening the constitution of the Committee and in a wide extension of its scope.

The crisis through which we have recently passed has had a profound effect upon the world. The spectacle of the most cultured and most highly developed peoples on this earth, armed with every offensive appliance which science and the inventive skill and ingenuity of men could suggest, in the throes of a death struggle must have made the angels weep. That dreadful harvest of death is past, but the aftermath remains. Some of it is evil, and the evil will persist for, it may be, generations. There is, however, an element of good in it, and the good, we trust, will develop and increase with increase of years. The whole complexion of the world—material, social, economic, political, moral, spiritual—has been changed, in certain aspects immediately for the worse, in others prospectively for the better. It behoves us, then, as a nation to pay heed to the lessons of the war.

The theme is far too complicated to be treated adequately within the limits of such an address as this; but there are some aspects of it germane to the objects of this Association, and I venture, therefore, in the time that remains to me, to bring them to your notice.

The Great War differed from all previous internecine struggles in the extent to which organised science was invoked and systematically applied in its prosecution. In its later phases, indeed, success became largely a question as to which of the great contending parties could most rapidly and most effectively bring its resources to their aid. The chief protagonists had been in the forefront of scientific progress for centuries, and had an accumulated experience of the manifold applications of science in practically every department of human activity that could have any possible relation to the conduct of war. The military class in every country is probably the most conservative of all the professions and the slowest to depart from tradition; but when nations are at grips, and they realise that their very existence is threatened, every agency that may tend to cripple the adversary is apt to be resorted to—no matter how far it departs from the customs and conventions of war. This is more certain to be the case if the struggle is protracted. We have witnessed this fact in the course of the late war. Those who, realising that in the present imperfect stage of civilisation wars are inevitable, yet strove to minimise their horrors and formulated the Hague Convention of 1899, were well aware how these horrors might be enormously intensified by the applications of scientific knowledge, and especially of chemistry. Nothing shocked the conscience of the civilised world more than Germany's cynical disregard of the undertaking into which she had entered with other nations in regard, for instance, to the use of lethal gas in warfare. The nation that treacherously violated the treaty of Belgium and even applauded the action, might be expected to have no scruples in repudiating her obligations under the Hague Convention. April 25, 1915, which saw the clouds of the asphyxiating chlorine slowly wafted from the German trenches towards the lines of the Allies, witnessed one of the most bestial episodes in the history of the Great War. The world stood aghast at such a spectacle of barbarism. German *kultur* apparently had absolutely no ethical value. Poisoned weapons are employed by savages, and noxious gas had been used in Eastern warfare in early times, but its use was hitherto unknown among European nations. How it originated among the Germans—whether by the direct unprompted action of the Higher Command, or, as is more probable, at the instance of persons connected with the great manufacturing concerns in Rhineland, has, so far as I know, not transpired. It was not so used in the earlier stages of the war, even when it had become a war of position. It is notorious that the great chemical manufacturing establishments of Germany had been, for years previously, sedulously linked up in the service of the war which Germany was deliberately planning—probably, in the first instance, mainly for the supply of munitions and medicaments. We may suppose that it was the tenacity of our troops, and the failure of repeated attempts to dislodge them by direct attack, that led to the employment of such foul methods. Be this as it may, these methods became part of the settled practice of our enemies, and during the three succeeding years—that is, from April, 1915, to September, 1918—no fewer than eighteen different forms of poison—gases, liquids, and solids—were employed by the Germans. On the principle of Vespasian's law, reprisals became inevitable, and for the greater part of three years we had the sorry spectacle of the leading nations of the world flinging at one another the most deadly products that chemical knowledge could suggest and technical skill contrive. Warfare, it would seem, has now definitely entered upon a new phase. The horrors which the Hague Convention saw were imminent, and from which they strove to protect humanity, are now, apparently, by the example and initiative of Germany, to become part of the established procedure of war. Civilisation protests against a step so retrograde. Surely comity among nations should be adequate to arrest it. If the League of Nations is vested with any real power it should be possible for it to devise the means and to ensure their successful application. The failure of the Hague Convention is no sufficient reason for despair. The moral sense of the civilised world is not so dulled but that, if roused, it can make its influence prevail. And steps should be taken without delay to make that influence supreme, and all the more so that there are agencies at work which would seek to perpetuate such methods as a recognised procedure of war. The case for what is called chemical warfare has not wanted for advocates. It is argued that poison gas is far less fatal and far less cruel than any other instrument of war. It has been stated that "amongst the 'mustard gas' casualties the deaths were less than 2 per cent., and when death did not ensue complete recovery generally ultimately resulted. . . . Other materials of chemical warfare in use at the armistice do not kill at all; they produce casualties which, after six weeks in hospital, are discharged practically without permanent hurt." It has been argued that, as a method of conducting war, poison-gas is more humane than preventive medicine. Preventive medicine has increased the unit dimension of an army, free from epidemic and communicable disease, from 100,000 men to a million. "Preventive medicine has made it possible to maintain 20,000,000 men under arms and abnormally free from disease, and so provided greater scope for the killing activities of the other military weapons. . . . Whilst the surprise effects of chemical warfare aroused anger as being contrary to military tradition, they were minute compared with those of preventive medicine. The former slew its thousands, whilst the latter slew its millions and is still reaping the harvest." This argument carries no conviction. Poison gas is not merely contrary to European military tradition; it is repugnant to the right feeling of civilised humanity. It in no wise displaces or supplants existing instruments of war, but creates a new kind of weapon, of limitless power and deadliness. "Mustard gas" may be a comparatively innocuous product as lethal substances go. It certainly was not intended to be such by our enemies. Nor, presumably, were the Allies any more considerate when they retaliated with it. Its effects, indeed, were sufficiently terrible to destroy the German *moral.* The knowledge that the Allies were preparing to employ it to an almost boundless extent was one of the factors that determined our enemies to sue for the armistice. But if poisonous chemicals are henceforth to be regarded as a regular means of offence in warfare, is it at all likely that their use will be confined to "mustard gas," or, indeed, to any other of the various substances which were employed up to the date of the armistice? To one who, after the peace, inquired in Germany concerning the German methods of making "mustard gas," the reply was: "Why are you worrying about this when you know perfectly well that this is not the gas we shall use in the next war?"

I hold no brief for preventive medicine, which is well able to fight its own case. I would only say that it is the legitimate business of preventive medicine to preserve by all known means the health of any body of men, however large or small, committed to its care. It is not to its discredit if, by knowledge and skill, the numbers so maintained run into millions instead of being limited to thousands. On the other hand, "an educated public opinion" will refuse to give credit to any body of men of science who employ their talents in devising means to develop and perpetuate a mode of warfare which is abhorrent to the higher instincts of humanity.

This Association, I trust, will set its face against the continued degradation of science in thus augmenting the horrors of war. It could have no loftier task than to use its great influence in arresting a course which is the very negation of civilisation.

The British Association at Edinburgh.

ABSTRACTS OF PRESIDENTIAL ADDRESSES.

THE presidential addresses delivered at a meeting of the British Association are now published in volume form, thus providing a convenient annual record of authoritative thought and opinion upon a wide range of scientific subjects. The title of the volume just issued is "The Advancement of Science, 1921"; the publisher is Mr. John Murray, and the price 6*s.*, or to members attending the Edinburgh meeting 4*s.* 6*d.* The address of the president of the Association, Sir Edward Thorpe, is also on sale separately, price 1*s.* Following our usual custom, we print this address in full in the present issue, and we hope, in succeeding issues, to publish the parts of addresses of presidents of sections of interest to scientific readers generally. The subjects dealt with in these addresses are described in the subjoined abstracts.

PROBLEMS OF PHYSICS.

In Section A (Mathematics and Physics) Prof. O. W. Richardson will review in his address the present state of a number of leading problems now engaging the attention of physicists. After a brief reference to relativity, the far-reaching importance of the discoveries relating to the nature of the nuclei of atoms being made at Cambridge by Sir Ernest Rutherford will first be emphasised. The conditions which govern the emission of electrons by matter will then be considered broadly. This involves a review of the present state of our knowledge of thermionic emission and of photoelectric action. These two groups of phenomena are shown to be very closely, perhaps inseparably, connected. Nevertheless, the claim that thermionic emission is merely a manifestation of the photoelectric activity of a body under its own thermal radiation will not withstand a critical examination. The same is true of the wider claim which has been put forward that all chemical action is a similar and immediate effect of radiant activity. There is not, in either case, enough radiation to produce the observed results. The controversy which has lasted more than a century as to the origin of contact potential differences will be referred to, and it will be shown that the new phenomena supply the material required to settle this dispute. All three groups of phenomena are, in fact, closely related, and have undergone similar vicissitudes. In conclusion, attention will be directed to the rapid unification of light and X-ray phenomena as the result of recent investigations.

CHEMISTRY AND LIFE.

Four years of warfare having given the public some insight into the relation between chemistry and industry, with perhaps undue stress on utilitarian aspects of the science, it appears desirable to emphasise also the fundamental part played